2.3.1.4 City B Data: In Figure J.6 the 1,500 foot data plots of runs are those flown roughly parallel to the course of the river and in Figure J.7, the data is for runs flown perpendicular to the river. As expected, Run 3 shows a higher level than the others in this set. The higher level is confirmed in Table J.3. However, Run 9 in Table J.4 was expected to be at a high level, but was not due to its location over the city. Run 11 was the run with the highest mean for the second set flown perpendicular to the first. Run 11 was the furthest out from Center City. For plots of runs at 5,000 and 10,000 feet see Figures J.8 and J.9. Analysis of these runs are presented in Tables J.5 and J.6.

The grand means for the runs at 1500, 5000, and 10,000 were respectively -88.16, -91.86, and -82.98. The grand mean excludes Run 17 in which the DPO apparently drifted off frequency from 117.9994 MHz and had a calculated mean of -143 dBm. The single Run #16 was probably nearly over the same course as Run #3 and therefore could be expected to be a high level. No explanation is given as to why Run 15 over the same course did not also show a high mean. The representative spectrum analyzer images are presented in Figures J.10 and J.11. The 117.9994 MHz CATV signal is clearly seen above the noise level and occupies a significant portion of the swept spectrum.

2.3.1.5 City K Data: The data for City K is representative of cities for which the 117.9994 MHz CATV signal was not apparent in the spectrum analyzer image. No plots of data are shown. Statistical treatment of the data are tabulated in Tables J.7 through J.9. The grand mean for the signals is -94.6 dBm. This level represents the peak level of noise rather than signal.

2.3.1.6 Grand means comparison: The aperture over which the maximum desired signal was selected was approximately 20 kHz and is representative of a VOR receiver aperture. The grand means for cities/airports was found to be significantly different. This difference is largely due not to the difference in CATV signal measured, but due to the ambient noise signals appearing in the measurement aperture. The Table J.10 presents these grand means for comparison.

2.3.1.7 City C Data: In Table J.11 and J.12 there is no significant differences shown between the grand means of Runs 1 to 13 and Runs 21 to 27 which have means respectively of -86.9 dBm and -86.8 dBm, respectively. The radiated signal was not seen on the spectrum analyzer even when the several dipoles were attched to the CATV system. An additional test was conducted at City C to determine if a heterodyne signal existed on the VOR receiver audio output when tuned to the CATV pilot carrier. The pilot carrier frequency was the same as the City B VOR, 112.5 MHz.

The result was an audio beat frequency which was received on the VOR test receiver at 450 meters (1,500 feet) and above to 3,000 meters. The heterodyne blocked the VOR code identification. The distant VOR is about 90 kilometers from City C. Subsequent tests by the FCC confirmed that the CATV was responsible for the heterodyne. Other effects to the VOR system were not observed during the flight test. Subsequent laboratory tests (see Sections 2.3.1.8 and 1.4) were made and the results indicate that with an operational

VOR signal of 5 microvolts, an interfering signal of -109 dBm was sufficient to cause the flag to be present on the VOR indicator, provided the interfering signal is present on either the ±9960 Hz or the ±30 Hz spectral components of the VOR signal (need not be phase locked). In other portions of the VOR spectrum the interference signal required to cause a flag could be as high as -103 dBm.

2.3.1.8 Laboratory VOR interference tests.

The frequency interference measurements were accomplished using the equipment configuration shown in Figure J.12. A minimum VOR signal of 5 uV was selected for the laboratory test which is the signal level employed in FAA airborne checks.

The signal levels that will cause a "FLAG" indication (non-operational status of the receiver) are shown in Figure J.13, as evidenced. Signals as low as -109 dBm and -106 dBm will cause a flag at ± 30 Hz and ± 9,960 Hz, respectively, from the tuned receiver frequency. These effects are the results of zero beats occurring between the interfering signal with normal carrier and subcarrier from the VOR. At all levels of test, if the interfering signal was modulated it was audible when the receiver audio output was monitored with earphones. Additional laboratory analysis is in OT Report 74-39.[17]

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[17] Harr, T., Haakinson, E., and Murahata, S., "Electromagnetic Capability of Simulated CATV Signals and Aircraft Navigation Receivers," O.T. Report 74-39, June 1974.

It can be inferred that a CATV rf signal radiating at a frequency employed by a VOR station can cause the receiver to be unreliable if CATV leakage occurs. Particularly, if the aircraft is over the on-frequency CATV leakage area and the VOR receiver is tuned to a distant VOR station. The field intensity of distant VOR station is evident from figure J.14, extracted from an FAA Report.[18].

### 2.3.2 Communications/Navigation receiver data.

The communications receivers were tuned to 118.0 MHz and the AGC recorded. However, due to the high non-linearity of the response at the low level of desired signal, little information was gained from the receivers AGC recording.

The VOR navigation receivers were not operated since 118.0 MHz could not be tuned. The nearest adjacent channel would not have yielded useful results.

Uncertainities: Due to an INS program variation no INS data were recorded. The loss of INS position information had little effect on the value of other data recorded. The principal DPO problem appears to be the equipment's inability to deal with the adjacent ambient noise level which varies

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18 Del Balzo, J. M. and Willey, V. E., "VORTAC Relative Field Intensity," Final Report FAA Task No. 115-905-27, November 1961.

considerably from city to city. The tests for Arlington were modified so that the ambient noise could be measured separately from the on-frequency interfering signals. Unfortunately a failure in the DPO prevented recording with the broadband equipment.

A second error resulted from a programming problem that caused every value of the 11th sample to appear to be several dB higher than those preceding and following. The effect was not great since it was a constant added to all runs and did not affect between run comparison and results in less than 1 dB effect on the mean in the -90 dB level.

## 2.4 Airspace measurements with AGC of communications receiver.

In some cases ground measurements may be infeasible. For example, both making and interpreting measurements would be difficult if a significant portion of the cable plant were installed in hi-rise buildings. In such cases an airspace measurement procedure would be a useful alternative to ground-based tests. Measurements described in Sections 2.2 and 2.3 require large aircraft and expensive equipment for data generation, recording, and analysis. Such measurements are not feasible for individual cable system operators or for enforcement personnel. In this section there is described a much simpler and less expensive technique for making airspace measurements of cable leakage.[19]

The measurement is based on the use of the automatic gain control (AGC) voltage of an aeronautical communication receiver as an indicator of the electric field $E$ due to cable leakage signals. The AGC voltage is a function of the power input to the receiver, which is in turn a function of antenna characteristics and the incident field $E$.

In other parts of this report the criterion used for acceptable cable system performance is that the 90th percentile input power to an aeronautical receiver at 450 meters altitude should be less than -100 dBm. For the simpler measurement proposed here it is necessary to adopt a criterion based on

[19] Based on techniques developed by Robert V. C. Dickinson.

electric field intensity E at the 450 meter altitude. The Federal Aviation Administration has previously suggested 10 $\mu V/m$ as the maximum acceptable field intensity from cable signal leakage.[20] Under some reasonable assumptions about antenna performance, this field corresponds approximately to the -100 dBm criterion used elsewhere in this report. Thus, we recommend that a field of 10 $\mu V/m$ at 450 meters altitude (approximately 1500 ft.) be used as the standard against which cable system performance should be judged.

Given this criterion, the recommended measurement procedure is as follows:

(1) Using horizontal crossed dipoles mounted one quarter wavelength above a conducting ground screen at or near ground level within the area served by the cable system, and an unmodulated carrier signal, create a reference field of intensity 10 $\mu V/m$ at a height of 450 meters above the cable system. The signal should be within the VHF aeronautical radio band, and on a frequency not used by an aeronautical radio service within 111 kilometers (60 nautical miles) of the cable system.

(2) Using a conventional aeronautical antenna having either a horizontal polarity or no strong polarization sensitivity, mounted on a metal-skinned aircraft, fly through the reference field at 450 meters altitude, recording on a strip chart recorder the AGC voltage of an aeronautical radio receiver tuned to the reference carrier.

(3) Remove the reference carrier, and impose upon the cable system an unmodulated carrier at the same frequency, at the same power level as the highest carrier or other signal component carried by the cable system in the VHF aeronautical radio band.

(4) Fly several paths at 450 meters, on several different headings (or a grid), over the cable system, recording the AGC volatage just as was done with the reference carrier. The flight path should overfly any particular portion of the cable system which is known or suspected of having worse leakage performance than other portions of the system.

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[20] Included in the record of FCC Docket 21006.

(5) Cable system performance is considered acceptable if the peak of a smooth curve drawn through the "center of gravity" of the (noisy) trace due to cable signal leakage is lower than the peak of the similar curve drawn through the trace made by the reference field.

Examples of AGC voltage as a function of input power for a particular receiver, a reference field recording, and a record made during a flight over a cable television system are shown in Figures F.134, F.135 and F.136, respectively.

Note that except for polarization effects antenna and transmission cable characteristics are "calibrated out" in this measurement process. There may be, however, a bias error which is not eliminated in this or any other airspace measurement described in this report. That error relates to whatever anisotropy in polarization sensitivity or gain the aircraft antenna may possess. The reference field emanates from a point source, and has a known polarization (horizontal). But the cable leakage signal is the sum of a larger number of sources, each of which has an unknown polarization, magnitude and direction of propagation. Thus, the AGC voltage record may not reflect the maximum field intensity at every point in space during the flight over the cable system. This potential error is ignored, however, both in this measurement process and in the measurements reported in Sections 2.2 and 2.3, on two grounds: (a) as discussed in Section 2.1.5, cable leakage fields do not seem to exhibit strong polarity in the airspace, and (b) antennas used in the tests described here correspond reasonably closely to antennas actually used on aircraft which would experience any cable signal interference which might exist.

We note that if the ambient electromagnetic noise above the cabled city itself exceeds the reference field, then the measurement procedure described would automatically compare cable leakage fields with the ambient noise rather than with the reference field. This would also constitute a fair test for cable signal leakage. If cable leakage does not exceed ambient noise, it would not generally be a significant source of radio interference. If it is suspected that ambient noise is being measured, another fly-over should be conducted with no test carrier on the cable. This will establish the true center of gravity of the noise.

Urban electromagnetic noise is a funtion of time of day, because automotive traffic is a primary source of that noise. Therefore, flyover tests should, if possible, be made at times when the background noise is significantly lower than the peak of the standard reference field. Very early morning, mid-afternoon or late evening hours provide daylight for the tests (at least in summer) and at the same time should be the quietest periods.

In connection with this latter comparison -- with ambient noise rather than with a calibrating field -- note that it may be possible to detect coherent leakage signal with a narrow band (say, 1 kHz) detector, while the same signal might not be detected by an aeronautical receiver having an intermediate frequency bandwidth of 25 or 50 kHz. In practice, this is not considered a serious problem, since any effect would be marginal. It is suggested, however, that to minimize the effect of bandwidth, a receiver having a nomimal half-power bandwidth of no more than 25 kHz should be used. In order to promote uniformity of results, an aeronautical communications receiver used for the test should meet the relevant standards of the Radio Technical Committee for Aeronautics (RTCA).

Both types of strip chart recordings -- those from the reference field and those from cable signal leakage -- will be more or less "noisy" traces. In general, the cable leakage signals will yield the more irregular trace (see figures F.135 and F.136). A smooth curve through the "center of gravity" of the noisy traces should be used for determining the maximum levels of both the calibrating field and the cable leakage fields. In the sensitive portion of the AGC voltage - power curve, the uncertainty associated with drawing a smooth curve through the noisy traces would typically be no more than 2 or 3 decibels. (Compare figures F.134, F.135 and F.136.)

## 2.5 Major individual leakage sources.

On the average, power flux at any point in space will be the sum of the power flux contributed by each cable leakage source. It was suggested, however, that phase addition could occur at some points in space. In that case large signals could result, as observed power at those points would be proportional to the square of the number of leakage sources rather than simply proportional to the number of leakage sources. It was also considered desirable in this program to measure the effect of one or a small number of leakage sources which produce fields much larger than those normally expected from a cable television system. Therefore successive measurement flights over a cable system having different numbers of artificially created known large leaks were made.

The cable system chosen for these measurements was a new system in Arlington, Virginia, which is part of the Washington, DC metropolitan area. At the time of the tests, the cable system was operating only about 40 kilometers of plant. The plant was constructed using modern connectors with built-in sleeves for leakage prevention. All cables and equipment housings were also designed for minimum leakage. Also, the system had been thoroughly examined for leakage prior to turn-on, which was only a matter of weeks prior to the tests. Thus it could be expected that there would be very few, if any, observable leaks other than those artificially introduced.

The artificial leakage sources consisted of "sleeve dipoles", made by turning back the outer flexible braid of lengths of RG-59 75 ohm coaxial cable, so that the center conductor and the braid each formed one half of a half-wave sleeve dipole tuned for 118 MHz. The dipoles, not perfectly linear, were connected as needed to high level amplifier output ports at various locations in the cable distribution system. The dipoles were allowed to hang in a more or less vertical position. When more than one dipole was used, the dipoles were separated from each other by distances of the order of one kilometer. The dipoles were energized with the usual unmodulated 118 MHz signal, at a level of 36 dBmV (-13 dBm).[21]

Measurements were taken by flying over the cable system with (a) no 118 MHz signal on the cable, (b) with a 118 MHz signal but no deliberately introduced leakage sources, (c) with one deliberate leak (the sleeve dipole), (d) with three leaks, and finally (e) with seven deliberate leakage sources. Each step was done at all three of the usual altitudes -- 450, 1500, and 3000 meters. Probability and cumulative distribution plots are given in Figures F.29-F.58.

Ground based measurements in the vicinity of one of these dipoles were made. A tuned dipole antenna was used with a field intensity meter (tunable voltmeter) for the measurements. At each measurement location the dipole was

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[21] dBmV = decibels relative to 1/75 microwatt. dBm = decibels relative to one milliwatt.

moved about over a 1 to 2 meter range until a maximum (or minimum) was noted. Then the dipole was rotated in the horizontal plane until a further maximum (or minimum) was observed, at which point point the field strength was measured and recorded. The highly variable nature of fields near cable leaks is indicated by the finding of differences between maxima and minima located in this way (within a meter or two of each other) from 1 to 15.5 decibels. (See Table G.2)

Three measurements with the dipole receiving antenna held in a vertical orientation were also made. In these cases, a maximum in the horizontal orientation was located and measured; then the antenna was rotated to a vertical orientation leaving the center of the dipole at the same place as for the horizontal measurement. The difference between horizontal and vertical polarizations in the three cases measured were +1, -2, and +5.5 dB. (The positive sign means the horizontal field strength was greater.) Judging from this very small sample, one would hardly expect to observe a strong polarization effect in the airspace, at least from leakage sources of this type.

Although the radiation pattern of the dipole sources may not be typical of radiation patterns of normal cable leaks, it is nevertheless interesting to note the very wide departure from the reciprocal relationship (free space assumption) between field strength and distance which is often called upon to "correct" field strengths made at one location to an equivalent value at a different distance from the leakage source. Table G.2 illustrates these departures from 1/r dependence, which are due to reflection, re-radiation, and absorption of the signal by buildings, overhead wires, and other objects generally present in an urban environment. The column labelled "calculated" gives the field strengths which would result if the field decreased as 1/r, compared to the measured value three meters from the sleeve dipole antenna. The last column gives the ratio (20 log E meas./E calc.), in decibels, of measured to calculated field intensity.

Not surprisingly, a high background noise/interference level was observed above Arlington and the Washington metro area. The 90th percentile level of the signals observed at 450 meters altitude was -109 dBm, when there was no 118 MHz signal imposed on the cable system. This may be compared with -126 dBm observed over City K, which is a smaller rural community more than 50 kilometers from a metropolitan area.

The cumulative distribution curve was not substantially different from the "no signal" curve when a signal at 118 MHz was placed on the cable system, with no artificially introduced leaks. Even with one sleeve dipole leak as described above the curve was not substantially different.

When three dipole leaks were introduced, however, the cumulative distribution curve did move upward by about 5 dB at the 10th and 50th percentile levels, and by 11 dB at the 90th percentile. When seven dipoles are present, the curve is higher than the "no signal" curve by 8 dB at the 10th and 50th percentiles and 12 dB at the 90th.

In the case of the 10th and 50th percentile, the comparison of the 3 and 7 dipole curves with the single dipole curve gives the results expected for power addition -- observed power proportional to the number of leaks. (10 log 3 = 5 dB, corresponding to the signal increase with 3 dipoles, and 10 log 7 = 8, corresponding to the seven dipole case.)

The behavior at the 90th percentile is erratic, however. Examination of the Arlington probability distribution curves (Appendix F) reveals a good bit of variability in curve shape at levels around and above the 90th percentile. This variability does not correlate well with parameters of the cable measurements, such as presence or absence of signal, number of dipoles, and aircraft altitude. The behavior of the 90th percentile level may be due in part to other factors, while the behavior of the median and 10th percentile signals represents the cable leakage signal behavior. There seems no reason to expect the higher level cable leakage signals to combine with each other in any different way from the lower level signals.

Similar behavior of signal vs. number of dipoles is observed at the 1500 meter (5000 feet) altitude, except that the curve representing signal on the cable system but no artificial leaks seems to be generally lower than the "no signal "curve". At 3000 meters (10,000 feet) the differences among all the curves is so small that it could easily be due to slightly different flight paths and different background noise conditions. Note that the "seven dipole" curve (Figure F.58) seems to indicate lower signal levels than does the "no signal" curve. The difference,however, may not be significant.

We conclude that:

(a) The artificial leaks introduced at Arlington produce electromagnetic fields significantly larger than fields observed from individual leaks in cable television systems;

(b) Small numbers of leaks of this magnitude would be observable with a narrow band receiver at 450 meter altitudes if they did occur, although even seven such leaks would produce fields only marginally greater than the squelch level of the most sensitive aeronautical communications receivers.

(c) At higher altitudes (3000 meters) above a metropolitan area such as Washington, there is some doubt that small numbers of leaks of the magnitude created in Arlington can be observed above background noise, even with narrow band receivers; and

(d) There is no evidence of phase reinforcement causing observed power to be proportional to the square of the number of leaks.

## 2.6 Heterodyne interference at City C.

During the course of the air measurements over City C, it was noted that a tone was detected in the aircraft navigation receiver when the receiver was tuned to a VOR transmitter about 90 km away operating at 112.5 MHz. The aircraft was at an altitude of aproximately 1500 meters (5000 ft.) when the beat note was detected. The beat note was also detected at an altitude of 450 meters, although the desired signal was very weak at this altitude. Although there appeared to be no effect on the navigation instrument indications, the tone did tend to mask the International Morse Code identification. Tests with the cable operator confirmed that a pilot signal carried by the cable on 112.5 MHz was the cause of the problem.

Even though City C is 10 nmi beyond the standard 40 nmi service volume (at 1000 feet) for this class of VOR, the station in question did offer extended service out to 80 nmi in the direction of City C. The heterodyne was discovered by listening to the audio channel of the VOR. No exhaustive tests were performed to see if this phenomena could affect the course indications of the receiver; however, no wandering needles or incorrect bearings were observed during the test. As stated in Section 1.4, if the audio identification channel of the VOR is not usable because of interference, the pilot would not know whether to trust the bearing indications. This in itself constitutes harmful interference to the service of the station in question, therefore, the CATV operator was requested to change frequency and he complied.

# 3. GROUND MEASUREMENTS AND ANALYSIS

## 3.1 Types of measurements.

Three types of ground measurements were conducted. The first type of measurement (Type A) corresponded very closely to the type of radiation measurements described in Part 76 of the FCC Rules and Regulations. A calibrated field intensity meter was used to make accurate measurements. The second type of measurement (Type B) utilized information learned from Type A measurements. A commercial cable leak detector with a meter was installed in the vehicle and a calibration chart was developed to relate meter readings on the leak detector receiver to actual measurements with the field intensity meter. The third method (Type C) employed the same automated measuring system used on the aircraft; however, the system was modified slightly for ground measurements.

## 3.2 Detailed point-by-point field intensity measurements (Type A).

Part 76 of the FCC Rules and Regulations describes a procedure to check for radiation from cable television systems. Basically, the procedure calls for a dipole antenna and a calibrated field intensity meter. The operator is instructed to orient the longitudinal axis of the dipole parallel to and under the cable. For the purposes of this test, the dipole was always at 3 meters (10 feet) from the cable. The antenna was moved along the cable until a maximum was found. The dipole was then rotated about its vertical axis and the maximum reading was considered to be representative of the leak. This procedure was utilized for all Type A measurements. Only leaks in excess of 50 μV/m were recorded.

### 3.2.1 Equipment used.

Measurements were made using a commercially available signal generator operating on 108.625 MHz.[22] The generator was part of a complete cable leak detector package. The generator was installed at the head end of the cable system being studied prior to making any measurements. The peak generator level was set to the peak carrier level of the closest adjacent video carrier, usually Channel 6. This arrangement assured that ground measurements would be made with the same carrier level as used for the airspace measurements.

The receiver portion of the leak detector was installed in the vehicle to alert operators of the presence of a cable leak. For the purposes of this test, leaks of less magnitude than fifty (50) microvolts per meter at three (3) meters from the cable were neglected. Operators drove the vehicle along and under the plant until a leak was noted on the leak detector. The vehicle would be stopped at each leak and a measurement was made, generally using a Singer 37/57 Field Strength Meter. The meter was operated in accordance with the manufacturer's instructions. During this process, the meter indications on the leak detector receiver were recorded so that a calibration curve between leak detector indications and actual field strength values could be developed for type B measurement (3.3). Note: The Kansas City FCC field office utilized the 37/57 for both the in-vehicle indications and the actual

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[22] The leak detector was a ComSonics "Sniffer" model S200S-1. Mention of brand names and model numbers in this report is for identification purposes only, and is not intended as an endorsement by this Committee, the FCC, or any other organization represented on the Committee.

measurements at three meters from the cable. The basic principal was the same as the commercial leak detector. The location of each leak and its strength were recorded on city maps.

The Type A procedure was not done in all cities because of the time required to complete the measurements. These measurements were accomplished in Cities A, C, E, F, G, H, J, and M. These cities provided the needed detailed data to be analyzed and provided a method to calibrate the commercial leak detector's arbitrary scale meter.

### 3.2.2 Uncertainties.

The Type A measurements provided highly accurate data concerning significant leaks in the cable systems. Although a few leaks could have been missed, it is unlikely that any high level leaks could have remained undiscovered, at least in that portion of the cable plant examined by the field crews.

## 3.3 Commercial leak detector measurements (Type B).

The commercial leak detector consisted of a signal generator to be connected to the head end, a receiver with an arbitrary scale meter and speaker, and a magnet mount vertical antenna to be placed on the roof of the vehicle. A calibration chart was developed from data obtained in Type A measurements to relate a given meter indication to a field strength at three meters from the cable. That chart is attached as Figure H.1. (The instrument had an internal calibration signal to assure uniform receiver gain for all measurements.) Each point shown on the graph represents the average of all points actually measured with a field strength meter. The straight-line graph intuitively gives one confidence in the calibration procedure. This intuitive feeling was confirmed by occasionally stopping the vehicle and making a Type A measurement to verify continued calibration accuracy. Based on the data points available, the one-sided 95% confidence interval is shown as the dashed curve in Figure H.1. The narrow confidence interval further confirms confidence in the curve.

For the Type B measurements, the vehicle was driven under the cable plant. When levels above 50 microvolts per meter were observed, the peak detector indication was recorded on a city map. These calibrated readings were later converted to field strength levels for analysis. All cities except City B were subjects of Type B measurements.

### 3.3.1 Initial procedure.

As in the Type A measurements, the signal generator was placed at the head end of the particular cable system. Its 108.625 MHz peak signal level was set to the level of the closest adjacent video signal. The vehicle was then driven throughout the cable plant and leakage levels were recorded manually on city maps.

### 3.3.2 Uncertainties.

The Type B measurements lack the accuracy and precision of Type A measurements. They do, however, provide a good indication of relative leakage levels. The confidence level in the calibration curve is sufficiently high to permit merging the Type A and Type B data sets for analysis.

## 3.4 Automated ground measurements (Type C).

The automated ground measurements utilized the same narrow band digital-recording equipment that had been installed in the aircraft. A conversion of the equipment was necessary to make the equipment suitable for ground measurements. Position information could not come from the Inertial Navigation System (INS) since the vehicle had no such system. Distance information could not be provided by the 200 hertz clock since the vehicle traveled at non-uniform rates. Also, the hard-copy printout needed to be more active due to the slower rate of data collection (slower average vehicle speed as compared to the aircraft).

### 3.4.1 Conversion of ITS equipment for ground measurements.

The first obstacle to overcome was the need for position and distance information. After reviewing many possibilities, including Loran C navigational system, a rather simple, but highly accurate procedure was adopted.

Position information was manually keyed into the magnetic tape by means of a keyboard. It was only necessary to enter position reports when the vehicle changed direction. Each intersection where the vehicle turned was named by the operators. A typical name would be "B2". In operation, for example, the operator would key in "B2". The driver would then follow a given road and no entry was necessary until a turn was made. At the turn the operator would key in the next intersection name, perhaps "B3". These names were recorded on city maps for use at a later time.

As with the air measurements, several samples per wavelength were required. The sample distance was chosen as 24 centimeters. Accurate distance information was provided by a "fifth wheel" attached to the back of the vehicle.[23] It provided a TTL compatible pulse to the ITS equipment at 24

[23] The wheel was constructed by Ralph A. Haller.

centimeter intervals. Distance information was captured by the rotation of a disc in front of a photoelectric source and detector. The disc was connected to the wheel proper and rotated at the same rate as the wheel. The disc was divided into sixteen wedges of alternating flat black and bright aluminum.

The output of the photodetector was a square wave whose duty cycle directly corresponded to distance traveled, so the device would operate at speeds from zero to over 40 miles per hour (the mechanical limit of the wheel).

With position and distance accounted for, it was necessary to supply the operator with hard-copy printouts at a sufficiently fast rate to assure him that the system was operating properly. The print rate was set to 500 samples and was of the same basic format as the airspace printouts (see Appendix D). The antenna used for the Type B measurements was employed for the Type C measurements.

One note of interest regards the powering of this equipment. Initially it was planned to operate the system with the equipment in the rear of a sedan and supply power by 12 VDC to 110 VAC inverters. The equipment required over 50 amperes from the vehicle electrical system. This proved to be excessive and the equipment was reinstalled in a van which had a 5 kilowatt gasoline engine powered generator.